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Offshore Extreme Wind Atlas Using Wind-Wave Coupled Modeling

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Extreme wind is a required design parameter to be estimated for offshore and coastal structures such as wind turbines and platforms and floating objects, to avoid structures obtaining damages from severe wind conditions.

Mid-latitude storms contribute to offshore extreme wind over the North Sea. It is often understood that offshore winds are relatively homogenous over space and the water surface can be described through the roughness length through the Charnock formulation. Though knowledge was gained that the Charnock formulation is not valid during storm conditions or in coastal regions where surface waves are breaking. In the last decades, researchers have been trying to introduce the wave impact to the atmospheric modeling through parameterization of derived wave parameters such as significant wave height, wave length and steepness, however all for open sea conditions.

It is shown in this study that during extreme wind storms over the North Sea, the wind field can be far from spatially homogeneous. About half of the time, open cellular structures are present, corresponding to strong and highly fluctuating (spatially and temporally) wind. It is also shown that for light to moderate winds, the many parameterization schemes in the literature give similar wave effect on the offshore wind, however, the differences between these schemes increase with increasing wind speed and become significant for winds greater than about 20 m/s. A wave boundary layer model (WBLM) was developed here to act as the interface between the atmospheric and wave modeling. WBLM uses one consistent set of equations, namely the momentum and kinetic energy conservations, to link the calculation in the wave model (here Spectral Wave model Nearshore SWAN) and that in the atmospheric model (here the Weather Research and Forecasting model WRF), thus avoiding the inconsistency that often occurs in parameterization schemes of the roughness length.

The modeling system WRF-WBLM-SWAN has been used to model 429 storms from 1994 to 2016 that contributed to the calculation of the extreme wind over Denmark and surrounding waters. The WRF model was setup with consideration of climatological storm path and wind variability, which helped the decision of the domain size and position, simulation length and resolution. The extreme wind was obtained using the selective dynamical downscaling method in Larsén et al. (2013).

Case studies show that WBLM outperforms the parameterization schemes for coastal areas and storm winds. Validation with measurements from several offshore sites in the North Sea suggests that WRF-WBLM-SWAN model system reproduces better offshore extreme winds over Denmark than using WRF alone.

Reference:

Larsén X., Badger J., Hahmann A. and Mortensen N. (2013): The selective dynamical downscaling method for extreme-wind atlases, *Wind Energy*, 16:1167-1182.